CRATER MORPHOMETRY AND CRATER DEGRADTION ON MERCURY: MERCURY LASER ALTIMETER (MLA) MEASUREMENTS AND COMPARISON TO STEREO-DTM DERIVED RESULTS.

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Introduction: Two types of measurements of Mercury's surface topography were obtained by the MESSENGER (MErcury Surface Space ENvironment, GEochemisty and Ranging) spacecraft: laser ranging data from Mercury Laser Altimeter (MLA) [1], and stereo imagery from the Mercury Dual Imaging System (MDIS) camera [e.g., 2, 3]. MLA data provide precise and accurate elevation meaurements, but with sparse spatial sampling except at the highest northern latitudes. Digital terrain models (DTMs) from MDIS have superior resolution but with less vertical accuracy, limited approximately to the pixel resolution of the original images (in the case of [3], 15-75 m).

Last year [4], we reported topographic measurements of craters in the D=2.5 to 5 km diameter range from stereo images and suggested that craters on Mercury degrade more quickly than on the Moon (by a factor of up to ~10×). However, we listed several alternative explanations for this finding, including the hypothesis that the lower depth/diameter ratios we observe might be a result of the resolution and accuracy of the stereo DTMs. Thus, additional measurements were undertaken using MLA data to examine the morphometry of craters in this diameter range and assess whether the faster crater degradation rates proposed to occur on Mercury is robust.

Method: Craters were mapped in five study areas of the northern smooth plains [5] of Mercury in an area totaling 3.35×10^5 km^2. Using ArcMap, all craters in the study areas were mapped, excluding obvious secondaries. CraterTools [6] was used to measured crater diameters, and the MDIS north polar mosaic was used as a basemap. In all, 332 craters in the D=2.5 to 5 km diameter were mapped. Each crater was evaluated to determine whether it had MLA shot data falling within 30% of the crater center. 112 of the craters in the dataset met this cutoff. Note that when the 30% requirement was met, most craters also had points much closer to their centers; 88 of the 112 had points within 20% of the crater center.

Using craters for which MLA sampling was deemed sufficient, depths were estimated using the difference between the elevation of the maximum MLA shot (usually along the crater's rim) and the elevation of the minimum MLA shot (in the crater's interior). Depth/diameter (d/D) ratios were then computed for comparison with the stereo-derived Mercury data and lunar data shown in [4].

Results: Figure 1 shows the d/D values obtained using the MLA data in this study. The median d/D observed on the northern plains in this diameter range is 0.13, which is significantly lower than the typical d/D~0.2 of fresh, simple craters [e.g., 7]. For comparison, the median d/D measured in this size range in regions with stereo MDIS DTMs [4] was 0.09. Although these results are modestly different, they are not inconsistent with each other because the northern smooth plains sampled with MLA were younger, on average, than the global sample (**Table 1)**. Thus, the broad global sample would be expected to be shallower and more degraded craters than the northern plains.

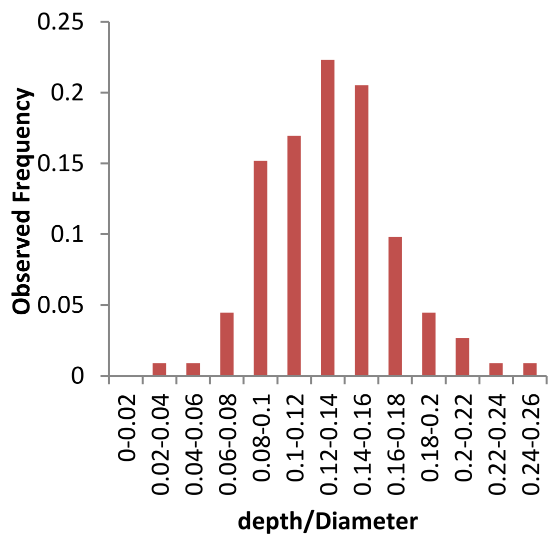

Figure 1. Frequency of depth/Diameter (d/D) values for the northern smooth plains of Mercury in the *D*=2.5 to 5 km size range measured with MLA.

Uncertainty in the MLA d/D Estimate: Although MLA data are more accurate than the stereo DTMs, the technique used for measuring d/D ratio here has important uncertainties arising from MLA's sparse sampling and the small size of the examined craters. First, because the maximum elevation is not measured everywhere on the rim, it may not be representative of the average rim elevation. Second, MLA tracks do not neces-

sarily sample the lowest point of a crater, and they integrate elevation information over the laser's footprint (typically ~20 to 30 m at these latitudes). Both minimum and maximum values are also sensitive to outliers.

These effects could conceivably make d/D measurements either too high or too low, although as with the measurements made on stereo DTMs [4], underestimation is more probable than overestimation. Nonetheless, the qualitative agreement of MLA and MDIS stereo measurements and a very large and significant difference between the typical d/D of 2.5 to 5 km craters observed on the Mercury and the Moon (**Table 1**). We conclude that this difference is unlikely to be a result of measurement errors alone.

Mercury	**Population Age, Ga**	**Model Age of the Median Crater, Ga**	**Median d/D, 2.5 to 5 km**
Northern Smooth Plains	3.70	3.53	0.13
Global DTM Sample	3.84	3.77	0.09
Moon			
Post-Maria	3.69	3.52	0.20
Highlands Sample, North and South Polar Plains	3.93	3.81	0.16

Table 1. Measurements of d/D evolution on the Moon and Mercury. The age model used for Mercury is the porous scaling model of [15], and the Neukum chronology is used for the Moon [16].

Discussion: Our results support the view [4] that craters in the 2.5 km to 5 km size range on Mercury are systematically much shallower than their lunar counterparts. We believe the most likely cause of this difference is enhanced crater degradation [e.g., 8].

A few alternative hypotheses are possible. The measured population is substantially contaminated by secondary craters, which are initially shallower than their primary counterparts. Secondary craters are indeed much more common on Mercury than the Moon [9], particularly at these kilometer-sizes. However, arguing that secondaries alone explain the Mercury/Moon differences seems unlikely for two reasons: (1) We attempted to exclude secondaries based on the usual morphological criteria (misshapen morphology, clustering, alignment). (2) A vast majority of the craters in our data would have to be secondaries to make the Mercury morphometry data similar to the Moon. This would in turn require that either age estimates of the northern plains are wrong and the plains are much younger than usually assumed, or that models for the primary impactor flux are greatly overestimated. We prefer the viewpoint that although secondary crater formation is an important process on Mercury that could contribute to the degradation effects we observe, unclassified secondaries are only a relatively minor contaminant to our data.

An alternative, more viable, explanation for the Mercury-Moon difference is that primary craters on Mercury are initially shallower or more variable in d/D than suggested by [7] (see also [10]). New evidence [e.g., 11] suggests that strength-controlled lunar craters (*D*~<100-200 m) may be shallower at formation than originally thought. However, because of Mercury's higher surface gravity, the strength/gravity transition should occur at a smaller diameter than on the Moon, not a larger one. So it would be unexpected to see a similar effect in the D=2.5-5 km size range on Mercury.

Conclusion: Our observations show that D=2.5 to 5 km craters on Mercury have shallower topography than expected, and likely experienced crater degradation at rates much faster than on the Moon. More rapid crater degradation on Mercury than the Moon is consistent with other observations, including faster regolith growth [12,13] and more rapid optical maturation and ray degradation [14]. This result also has broad implications for the evolution of Mercury's topography and its cratered surface.

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